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MODELING AND DEVELOPMENT OF A SOLAR POWERED DATES DRYER

Part 1 : Modeling and Experimental Analysis of the Solar Heat Collector

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Outline

- Dates in Oman
- Drying Dates, traditional and instrumented platforms
- Drawbacks of current drying platforms
- Solar energy potentials of Oman
- Rationale
- Geometry of prototype solar heat collector
- Experimental setup
- Modeling & simulation method
- Results
- Conclusion & future work

Sultanate of Oman

- **Geographical location :** southeastern coast of the Arabian Peninsula in Western Asia
- **Area :** 309, 500 km^2
- **Capital :** Muscat
- **Population:** 4,829,473
- **Weather:** very hot in summer and pleasant in winter

Figure 1. Map of Oman (Britannica.com)

Dates in Oman

- Date fruits are considered as the primary agricultural crop in Oman as it comprises **80%** of all fruit crops and around **50%** of the total agricultural area (Anon, 2016).

- **345,000 tons** is the annual production of dates in Oman.

- Date fruits considered one of the **most nourishing** natural foods as it consists of **70% carbohydrates (mostly sugars) and 15 to 30 % water content** (depend on the variety and on the maturity stage of the fruit).

- The flesh of dates contains **sugar (60 to 65 %), fiber (2.5%), protein (2%), fat, minerals, and pectin substances (each less than 2%)**.

- Date fruits are good source for **calcium, iron and potassium** (Zaid & de Wet, 2002).

(Source: flicker.com)

(Source: timesofoman.com)

(Source: flicker.com)

Drying

(Source: timesofoman.com)

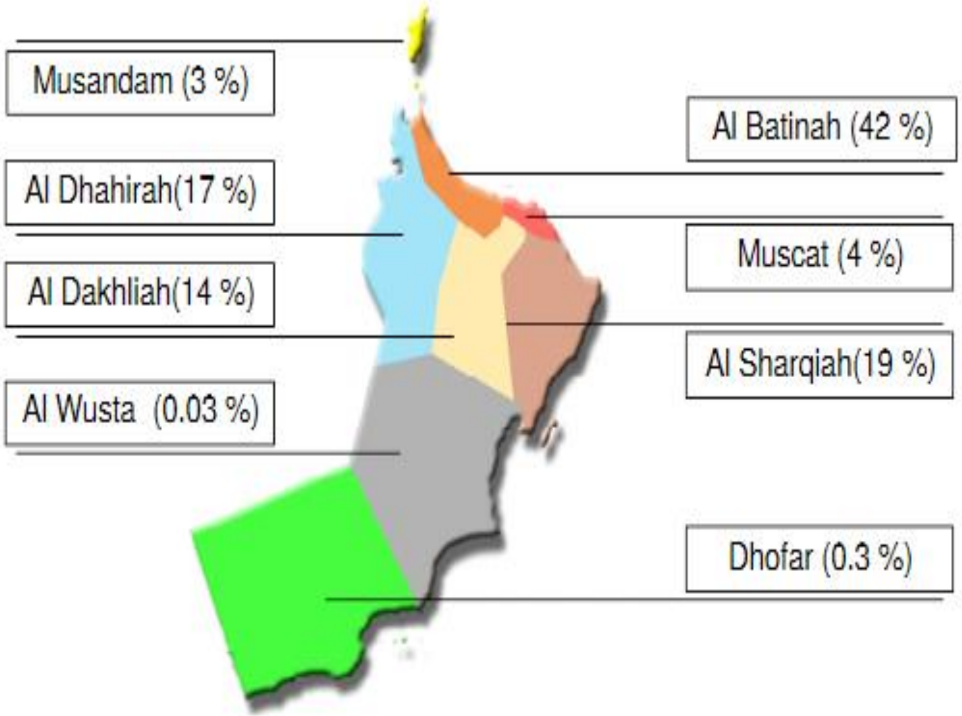


Figure 2. Regional distribution and percentage (from a total number of 7,795,786) of date palm trees in each region of the Sultanate of Oman.

Drying Dates: Open Sun Drying

Figure 3. Traditional sun drying using simple platforms

Open Sun Drying: Drawbacks

- Dates can get spoiled by weather conditions.
- Quality of the product can be reduced by the attack of animals, birds and insects.
- Poor dates quality (physical& nutritional).
- Poor hygiene.

Only 2.5 to 3.5 % is exported to global markets*

(*Mustayen et al. 2014).

Instrumented Solar dryers

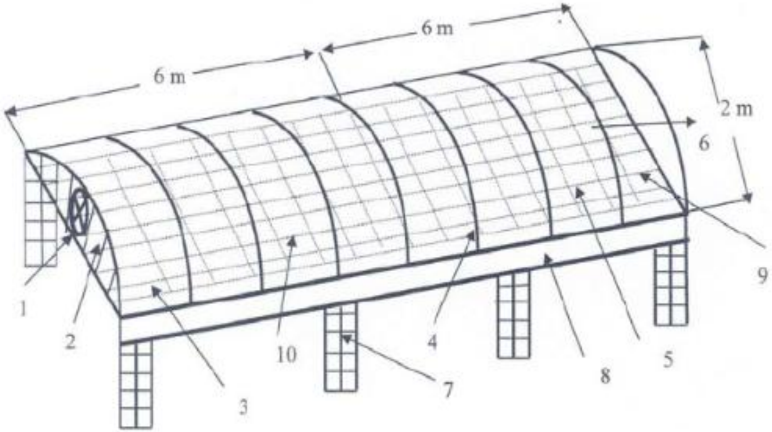


Figure 5 solar tunnel dryer

Basunia et al., (2010),

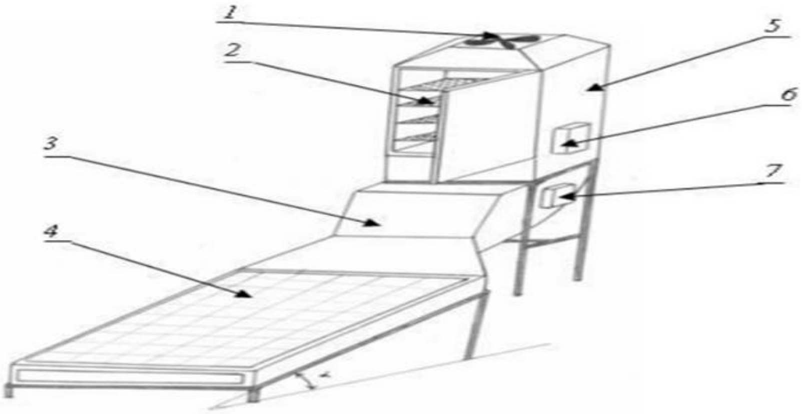


Figure 6 Forced convective solar dryer

Manaa et al (2013)

Solar Energy Potentials of Oman

- Oman has great potential for solar energy usages.
- Oman receives a daily 5.197 kWh/m^2 of solar energy radiation. (1897 kWh/m^2/year)

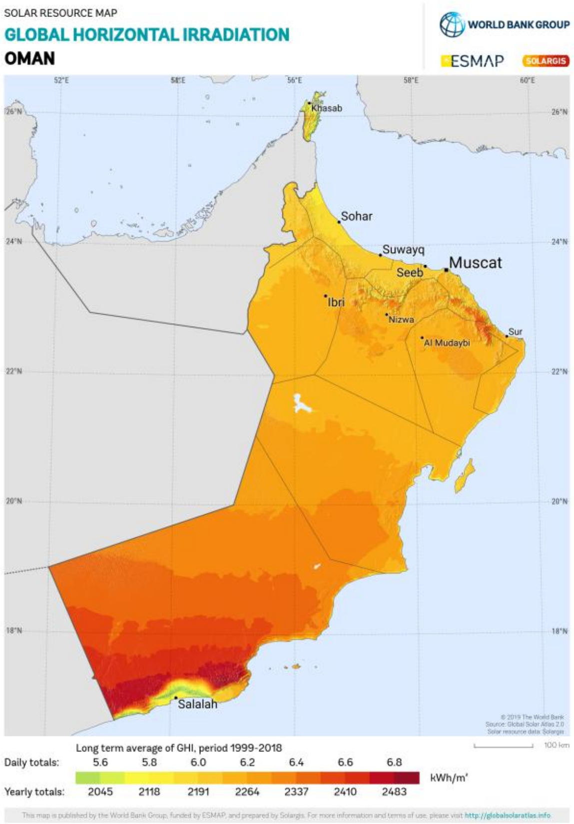


Figure 4. Global Horizontal irradiation (Source: solargis.com, 2019)

Rationale

- Greenhouse tunnel dryer (due to highest drying rate) and open sun drying (due to direct exposure to high temperature) had higher microstructural changes (Seerangurayar et al., 2019) .

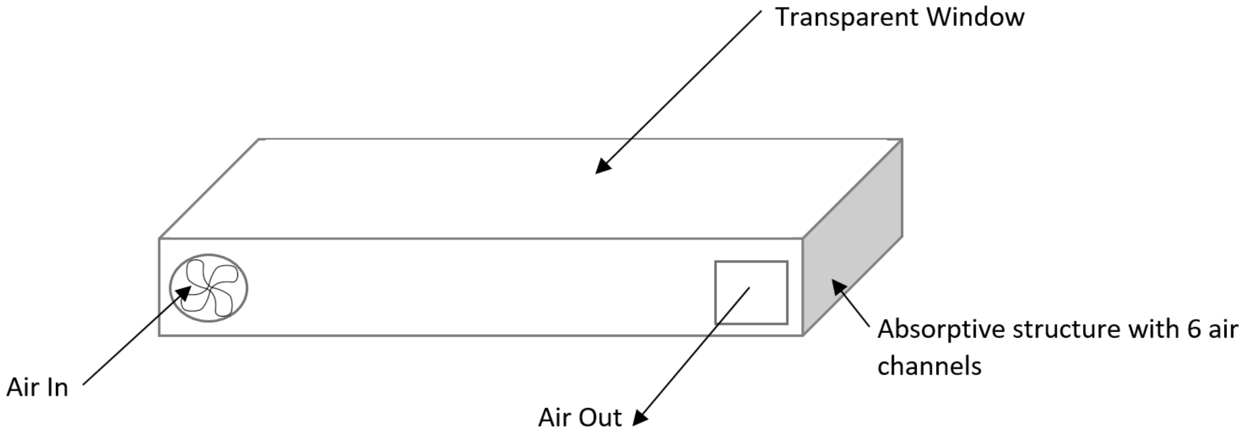
- Forced convective solar dryers could be improved in terms of size and technology to become more efficient and user friendly.

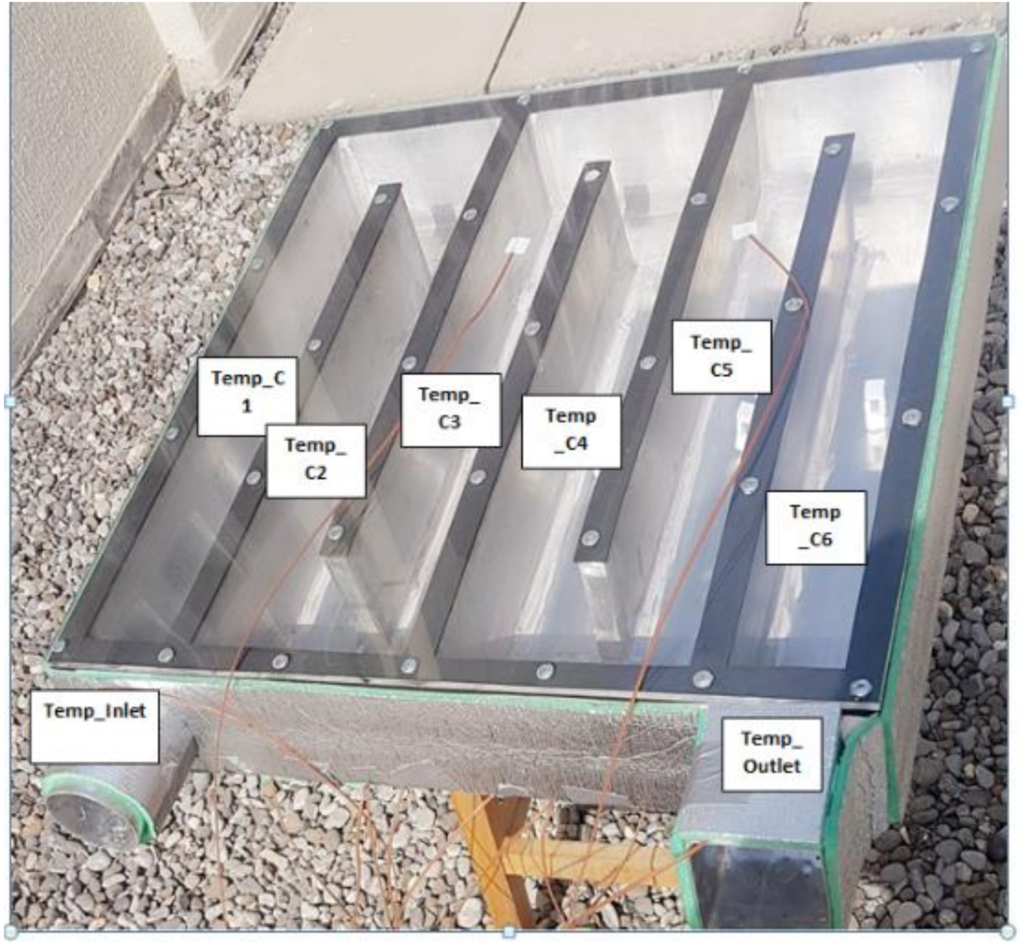
- Connecting remote villages and small farms in Oman to electrical grid is expensive and economically not feasible as these villages and farms are too far from the grid (Al Hatmi &Tan, 2013).

- Off-grid diesel-fueled generators are prohibitively expensive and unreliable because of the fuel high cost as well they need to be frequently maintained.

Geometry of the solar heat collector

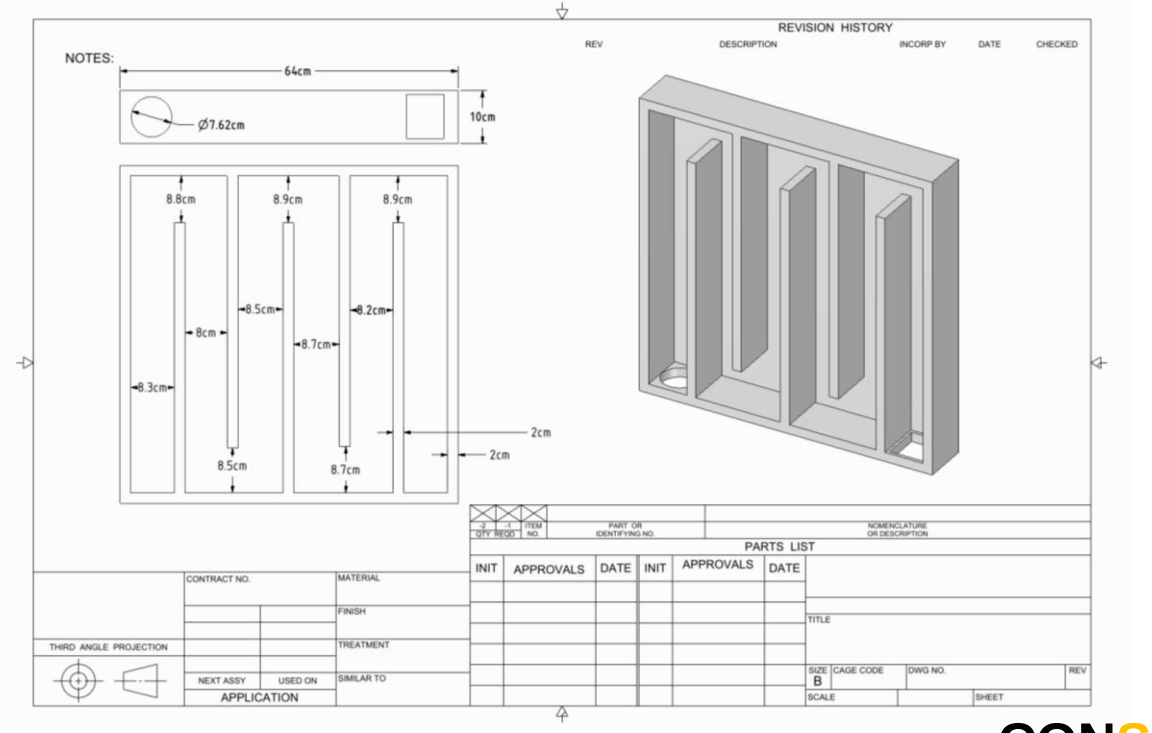
Overall Design



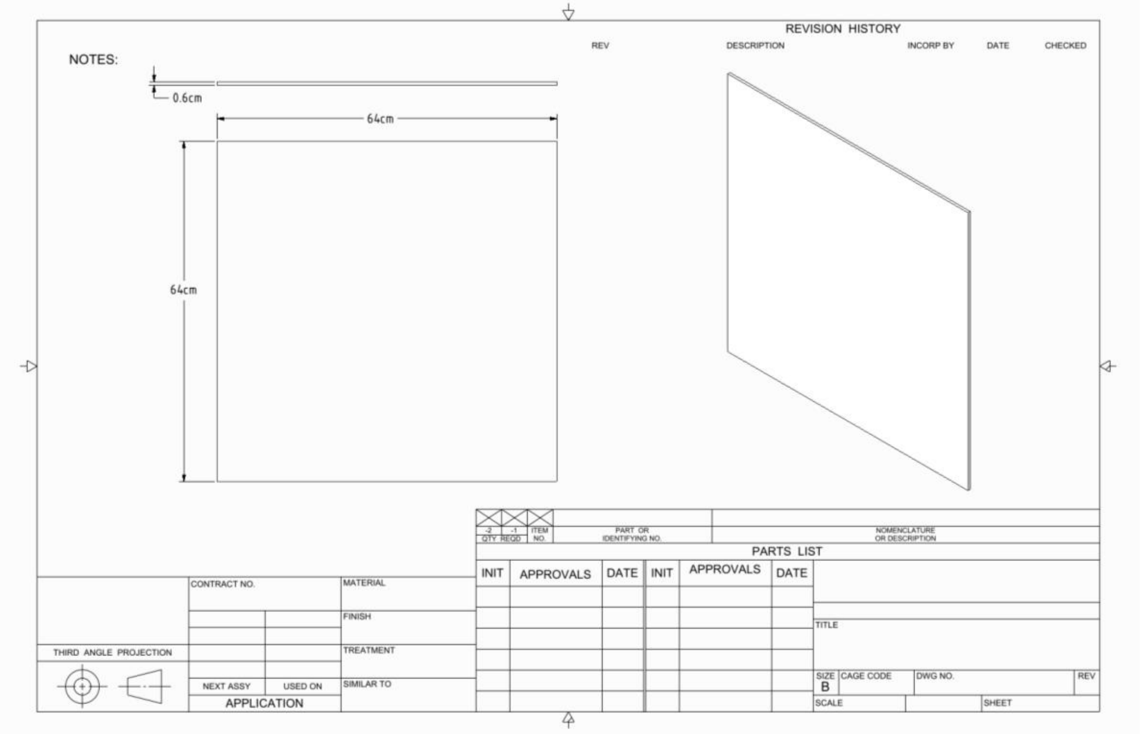

Temp_C
1
Temp_
C2
Temp_
C3
Temp
_C4
Temp_
C5
Temp
_C6
Temp_Inlet
Temp_
Outlet

Geometry of the Solar Heat Collector

Dimensions : Absorptive surface



Dimensions: Transparent window



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Experimental Setup

- Thermocouples in all 6 channels, transparent window, absorptive plate + inlet and outlet vents.
- Data logger.
- Weather station that measures:
  - Solar irradiance
  - Ambient air temperature
  - Relative humidity
  - Wind speed
- Photovoltaic panel to power the whole system.
- Exhaust fan with controllable speed.

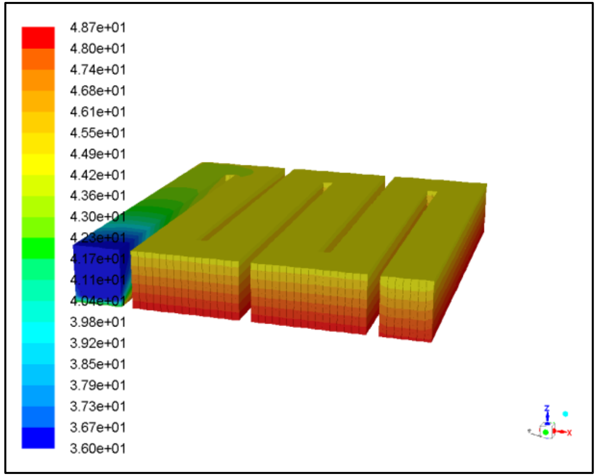
CFD Numerical Modeling Method

ANSYS Fluent Software

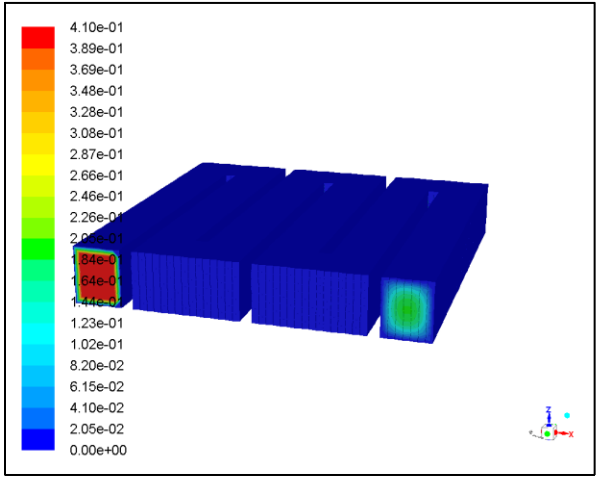
1. Create 3D geometry of the prototype
2. Model discretization (Meshing)
3. Define the models
   - Activate energy and viscosity equations
4. Select materials & and assign properties
   - Material properties
   - Air Properties
5. Set the boundary conditions
   - Air Inlet Velocity
   - Solar heat flux
   - Air inlet temperature
   - Convective heat transfer
6. Initialize Solution

Modeling & Simulation Results

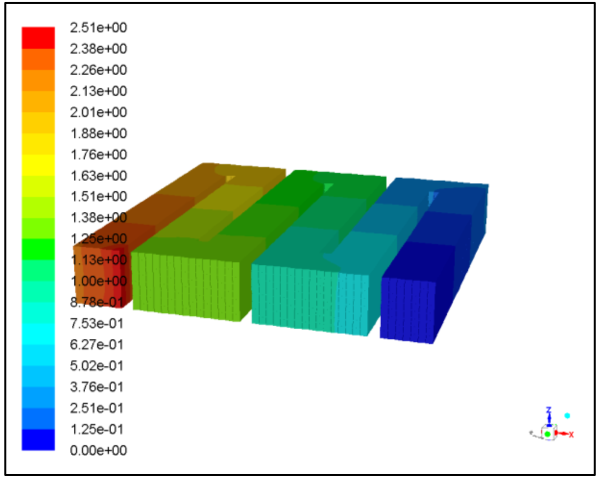
Model 1: Low Velocity (V_{in}= 0.40 m/s)



Temp (°C)

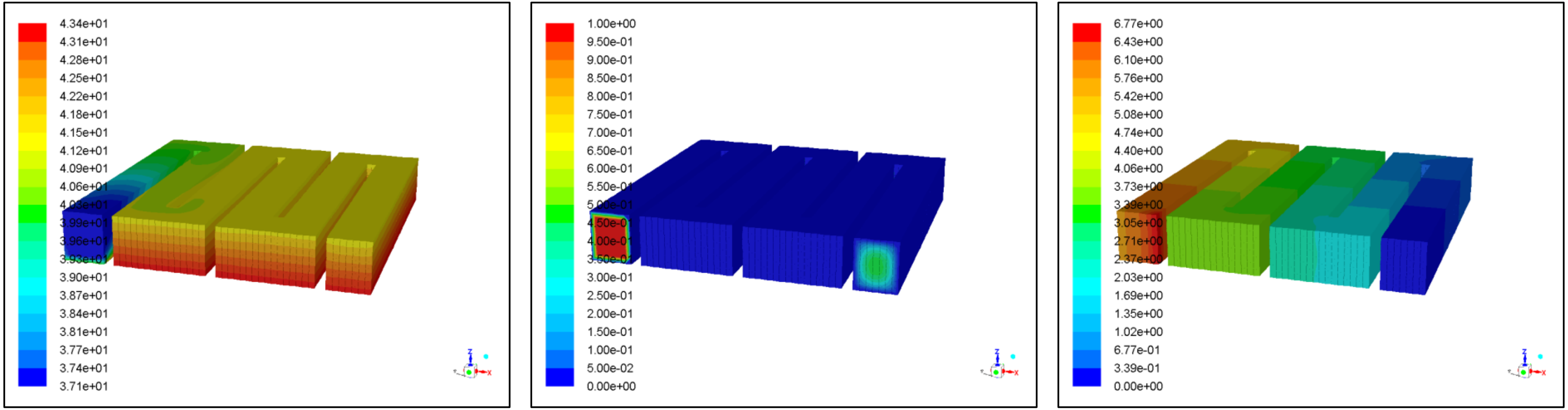


Velocity (m/s)



Pressure (pa)

Model 2: Medium Velocity (V_{in}= 0.65 m/s)



Temp (°C) Velocity (m/s) Pressure (pa)

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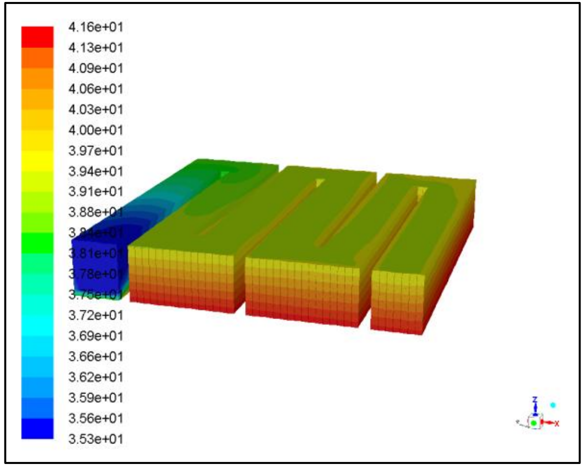
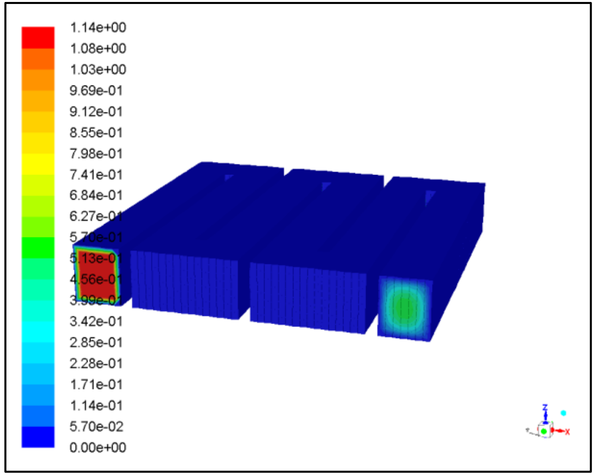
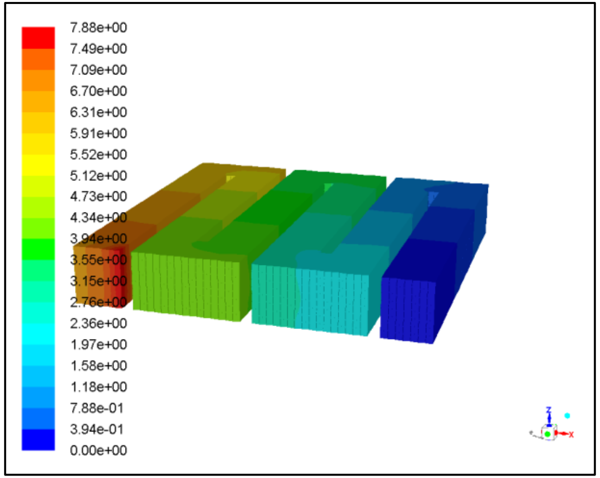
Model 3: High Velocity (V_{in}= 1.00 m/s)



Temp (°C)

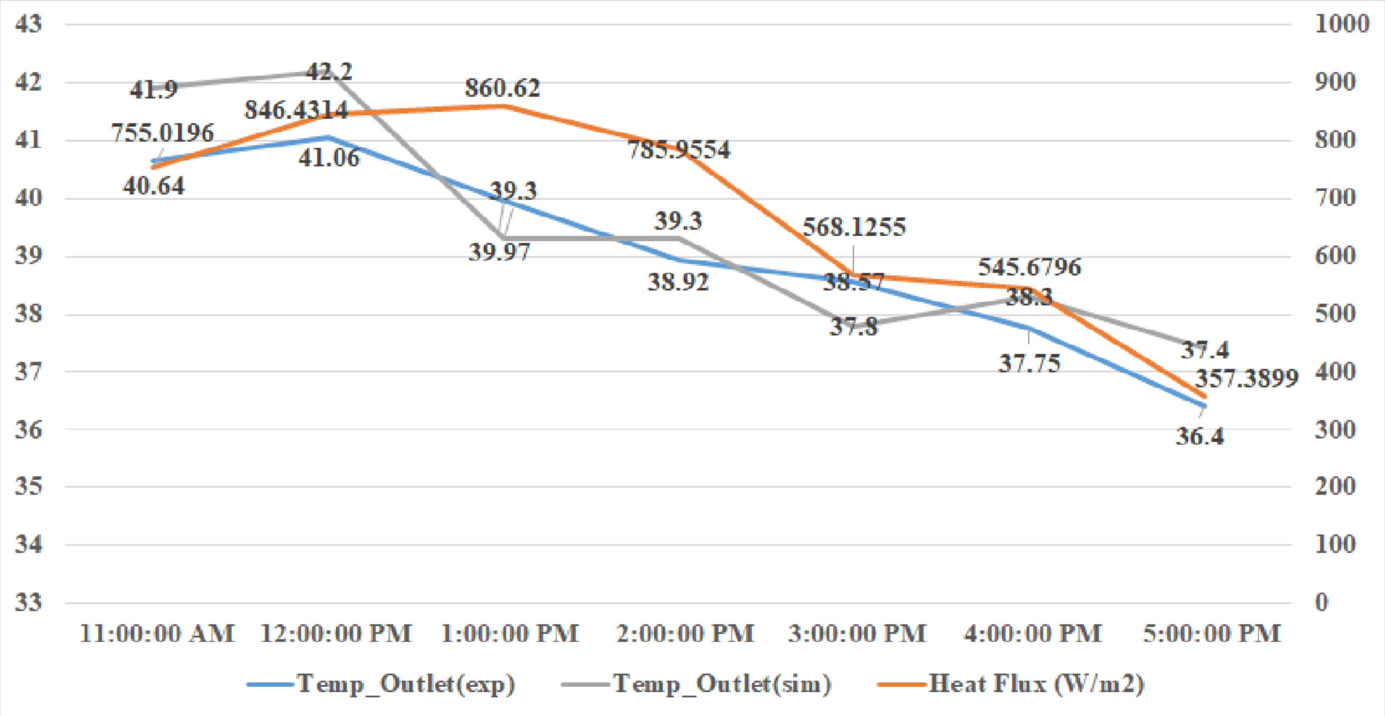


Velocity (m/s)



Pressure (pa)

Experimental Vs. Simulated Temp_Outlet



Conclusion

- Air inlet velocity Vs. Temperature difference (Outlet-Inlet) , as air velocity increases , the difference decreases and vice versa , true for model and experiment.

- Good conformation between values of outlet temperature measured experimentally & predicted by the simulation model.

Future Work

- Blacking of the absorptive surface.
- Addition of a solar tracking system to increase solar heat collection during the day.
- More experimental testing and modeling for better optimization.
- Develop the drying chamber , and testing drying of dates to develop the drying kinetics.
- Use of advanced electronics and microcontrollers to automate the drying process.
- Seek for commercialization potentials and distribution to local village farmers.

Thank You ....

Questions ?